Definition Workshop for the Deep Space Test Bed

June 9 - 10, 2003
Huntsville, Alabama

Workshop Report

National Space Science and Technology Center

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1.0 Introduction

The Deep Space Test Bed (DSTB) Workshop (WS) was held in Huntsville, Alabama on June 9 and 10, 2003 at the National Space Science and Technology Center (NSSTC). The primary objective of this workshop was to gather engineering design requirements from prospective users of the DSTB that will be used to develop a conceptual design of the DSTB facility. The WS also served to initiate direct communication between potential users of the DSTB and the engineering team tasked with its design.

The WS was announced through email distribution to past and present investigators with involvement in NASA's radiation shielding programs, through individual recommendations and postings at conferences. The attendees represented NASA centers, the National Scientific Balloon Facility (NSBF), universities and industry. Also in attendance were members of the NSSTC staff representing the different engineering disciplines that will be involved in the design effort. The WS was divided into two stages: the first stage consisted of presentations of a strawman design for the DSTB (and its subsystems) and presentations from individual scientists that described the science investigations and instrumentation that might utilize this facility. The second stage was an open discussion between scientists and engineers to bring to light details of the design that would allow a wide range of investigations to be conducted on the DSTB, including those presented at the WS.

This report documents the WS proceedings and contains the results of the WS. Those requirements identified in the WS have been integrated into the DSTB conceptual design described in the following sections. These requirements address accommodation of multiple experiments on the gondola for each flight, including mechanical and electrical power interfaces, data acquisition and storage, command and telemetry as well as operational details. The gondola must also accommodate the balloon-flight equipment provided by NSBF and used for flight operations. The DSTB conceptual design provides the physical interfaces to the NSBF systems for the entire payload without direct involvement of individual experiments. The DSTB team will also interface with NSBF regarding thermal design and structural certification for the entire payload. This report will be posted on the DSTB website and serve as information for future investigators that wish to utilize the DSTB.

A primary objective of the DSTB facility is to devise a flexible architecture to support current and future investigations to address those elements of the radiation shielding program suited for testing in a realistic deep space radiation environment. By implementing the DSTB facility with NASA's balloon program, which operates under reduced restrictions compared to space flight, the DSTB facility can easily adjust for different payloads and science priorities year to year. This flexibility in the DSTB exists at several levels: in the distribution of the shared resources by designing to fully utilize available resources, addressing the payload configuration on a system level for each flight, utilizing a payload selection process for investigations that considers yearly flight opportunities as well as the possibility for repeated investigations, and by tailoring operational strategies to reduce the impact of physical constraints that cannot be exceeded. This approach for developing the DSTB facility will ensure it can handle a wide range of investigations that will contribute to NASA's radiation shielding program.

The design requirements contained in this report will also guide development of interface details between the individual experiments and the DSTB subsystems. An interface definition document (IDD) will be developed for the DSTB facility that maintains updated interface requirements that govern the accommodation of individual payloads on the gondola. From this IDD an interface control document (ICD) will be developed for each payload. The ICD will contain sufficient technical detail to allow the DSTB engineers and the individual experiments to implement the interface from their home institutions. The IDD will be maintained on the DSTB website, while the ICD for individual experiments will be maintained by the DSTB and investigator teams. As the payloads will likely change for each flight, the IDD will be updated as needed to reflect current technologies and interface requirements for accommodation on the DSTB.

2.0 Project Scope

1. Need Statement

NASA must have assurance of the safety of the crew before committing to manned deep space missions. NASA must understand and develop radiation shielding methods (predictive capabilities, effective shielding materials, and verification) to protect crews during extended exposures to the cosmic radiation in deep space.

2. Goals and Objectives

- Provide a platform for direct exposure of multiple payloads to the full composition of galactic cosmic rays (GCR) and energy spectrum in a non-spaceflight program.
- Enable experimental validation of NASA's radiation transport codes in a realistic GCR environment.
- Test shielding effectiveness of typical as well as novel spacecraft materials in the GCR environment.
- Test new radiation monitoring instrumentation in the GCR environment.
- Measure the incident and induced radiation fields at the DSTB.

3. Mission and Operational Concept

Utilizing services provided by the National Scientific Balloon Facility, the DSTB will be launched on a Long Duration Balloon (LDB) from McMurdo, Antarctica (77.86 degrees south latitude) for circumpolar flights, nominally 20 days, traveling to the west and typically bounded between 73 to 82 degrees south latitude. Float altitudes for these balloons with payload are 115,000 to 130,000 feet. The DSTB will be able to accommodate multiple payloads per flight. Multiple flight opportunities are planned with one flight per year starting with 2005. Balloon campaigns in Antarctica occur in December and January during the Austral summer.

4. Assumptions

The DSTB will be built at the National Space Science and Technology Center (NSSTC).
A working group consisting of program and project scientists and engineers, managers and invited consultants will select scientific payloads for each flight opportunity.

5. External Interfaces for the System

The NSBF will provide the balloon and launch operations at the launch site in McMurdo, Antarctica, and operational services at the integration site in Palestine, Texas.

6. Major System Elements

Gondola Structure
Power System (solar panels, regulator, battery)
Flight Command and Data System
Thermal System
Standard Radiation Monitoring Sensors (DSTB provided)
Experiments (Investigator provided)
Balloon Support Equipment (NSBF provided equipment: Standard Instrument Package, solar panels, etc…)

7. Preliminary Schedule Milestones

2003	
June 09	DSTB Accommodation Workshop
Aug.18	DSTB Accommodation Study complete
Oct.	DSTB Informal PDR
Dec.	Science instruments and shielding materials selected: develop IDD and ICD with individual investigators
2004	
March	DSTB CDR
April	Submit NSBF Flight Application
March-Aug.	Fabrication and Assembly of DSTB
Aug.-Dec.	Integrate and test DSTB systems at NSSTC
2005	
Jan	Integrate science experiments and shielding materials at NSSTC
April	Conduct Engineering Flight at Palestine, TX.
August	DSTB gondola and NSBF SIP integrate and test at Palestine, TX
August	Flight Readiness Review
Dec.	Launch from McMurdo, Antarctica

3.0 Deep Space Test Bed Design Requirements

Power System Requirements

The power system for the DSTB provides power to the DSTB Flight Command and Data System (FCDS), the DSTB standard radiation monitors and the investigator experiments. The Standard Instrument Package (SIP) that contains the balloon flight control equipment obtains power from its own separate solar panels.

P1. The power system shall be capable of supplying on average 600 watts of power to the DSTB subsystems, DSTB standard radiation monitors and individual experiments continuously for the entire duration of the balloon flight.

Rationale & History of requirement: This requirement was agreed to during the DSTB workshop on June 9. The average 600 watts of power capability was what the strawman design could provide the DSTB subsystems and experiments using 3 solar panels on each side (total of 12 panels in an omni-directional configuration). The FCDS would be allocated 30 watts and the remaining power would be distributed between the investigator experiments and the DSTB provided standard radiation monitors. The duration for past LDB flights ranged from 10-30 days.

P2. The power system shall provide the experiments and the FCDS with unconditioned + 28 (±6) VDC.

Rationale & History of requirement: This requirement was agreed to during the DSTB workshop on June 9. The experimenters preferred unconditioned power and would condition the power on the experiment side to allow for more controlled power input to their experiment. The FCDS designer agreed that the FCDS would be able to function within this requirement.

P3. The power system shall provide a quick disconnect to isolate power from the solar panels and batteries (if there are batteries) for recovery operations.

Rationale & History of requirement: This requirement was derived from recommendations from the NSBF for safeing the payload for the recovery crew. Exposure to live wires during recovery creates a hazard. This requirement will be levied on the experiments as well if their batteries are potential hazards to the recovery crew.

P4. The power distribution system shall be designed to accommodate and control up to 20 separate branch circuits to deliver power to experiments and monitors.

Rationale & History of requirement: It is estimated that the DSTB may have approximately 10 experiments per flight. The capability of the power system to accommodate up to 20 experiments was selected to provide sufficient margin for any one flight. To control the power to each experiment, commandable latching relays will be used on each branch circuit. The commandable relays may be solid state or inductive.

P5. The power distribution system shall be capable of automatically discontinuing power to an experiment in an over current condition.

Rationale & History of requirement: Although relays may provide sufficient control for normal operations, a commandable current-limiting circuit breaker was deemed necessary on all power branch circuits to protect the DSTB's power system from abnormal events that may arise during the flight. In most cases a tripped circuit breaker would not be turned back on, but if analysis deemed that it was a single event, it would be prudent to have the capability to turn the experiment back on.

Thermal Requirements

Thermal requirements are derived from the Antarctic environment during launch, ascent, and at altitude. The Flight Command and Data System (FCDS) will be turned on and running during the launch operations. The environmental extremes occur during ascent (cold) and at altitude (hot). It is the goal of the DSTB to maintain the thermal operating temperature of the FCDS by passive means.

T1. The DSTB shall maintain thermal operating conditions for the FCDS between -10^{o} and $+50^{o}$ Celsius.

Rationale & History of requirement: The industrial operating range for most electronic components is between -40^{o} and $+85^{o}$ Celsius. Looking at past missions and experience in this environment, passive means such as paint, conductive radiators, heat conduction, insulation, and heat sinks should be sufficient to maintain the FCDS within thermal operating conditions. The FCDS needs to be functional on the ground prior to launch at McMurdo as well as during the entire duration of the mission.

T2. The thermal effects of the DSTB shall not push the SIP outside its thermal operating range.

Rationale & History of requirement: The SIP will be an integral part of the DSTB payload. A complete thermal model of the DSTB plus the SIP will be developed for each flight. The DSTB will provide inputs to the NSBF model that will predict the temperature ranges and gradients. The thermal system will be modified to assure that these ranges and gradients are mutually agreeable to both systems.

T3. Investigators will provide a thermal model of their experiment.

Rationale & History of requirement: The thermal requirements for various experiments were discussed during the workshop. It was agreed that the investigators should use their share of the resources to maintain a suitable temperature range during the mission. Experimenters would provide a thermal model of their experiment to the DSTB team. The DSTB would use passive techniques for thermal control during the flight.

Flight Command and Data System (FCDS) Requirements

D1. The FCDS shall be able to operate between -10^{o} and $+50^{o}$ Celsius.

Rational & History of requirement: See rationale for T1.

D2. The FCDS shall be functional prior to launch, during ascent, and in the float environment of the Long Duration Balloon Flight.

Rationale & History of requirement: At float altitude (115,000 to 130,000 feet), the atmospheric pressure will be approximately 3-5 millibars. The FCDS will need to function in this environment for the duration of its mission. One possible solution is the use of a pressure vessel for the FCDS components. Thermal equilibrium of all the electrical components within the FCDS would be maintained in a pressurized vessel to avoid thermal hot spots that can result at low pressures. The pressure vessel would also enable the use of commercial components for the FCDS. The risk of losing pressure in the box was evaluated and possible mitigation strategies to reduce the risk were addressed.

D3. The FCDS shall collect housekeeping data from the DSTB and the experiments and format the data to be downlinked through the SIP.

Rationale & History of requirement: The FCDS will collect housekeeping data from the DSTB and the experiments and format the data to be downlinked to the ground utilizing the capability established by the NSBF. The experiments will be required to provide a minimum set of housekeeping data to the FCDS for experiment monitoring (if they are active and in communication with the FCDS and are obtaining power from the DSTB). The amount of data will be constrained by the bandwidth available through the downlink path during the different phases of the mission. The telemetry rate for Line of Sight (LOS) will be 300 kbps. The telemetry rate allocated for LDB through TDRSS is 6 kbps, when available. LOS is typically available during the first 24 hours of flight only.

D4. The FCDS shall be capable of receiving commands sent from the ground station through the command link.

Rationale & History of requirement: Commanding will be limited to when there is uplink capability. In general, low rate commanding is usually possible and higher data rates will generally be available 10 minutes per hour through TDRSS.

D5. The FCDS shall be capable of recording science data from individual experiments.

Rationale & History of requirement: The science data acquired by the experiments will be recorded on the FCDS. The amount of data storage will be negotiated among the experiments. The downlink data rates are limited (see D3).

D6. The FCDS shall record the DSTB standard radiation monitor data.

Rationale & History of requirement: A standard instrument suite of radiation monitors will be part of the DSTB. This science data will be recorded on the memory available on the DSTB FCDS. The downlink data rates are limited (see D3).

D7. The FCDS shall be able to record a minimum of 20 Gigabytes of data.

Rational & History of requirement: A 20 Gigabyte hard drive was part of the strawman design presented during the DSTB workshop. The 20 Gigabytes of storage met the needs of all experimenters present at the workshop. The FCDS will have as a goal to have redundant memory capability and increased capacity.

D8. The FCDS shall be designed for autonomous operations during loss of telemetry.

Rationale & History of requirement: There will be times when there will be no link available between the DSTB and the operators on the ground. The FCDS shall be able to make some decisions with input from the housekeeping system and input from the experiments. The FCDS will test for nominal operating conditions and maintain acquisition of the science data. The FCDS will also determine out of limit conditions and safe the affected instruments.

D9. The FCDS shall provide 40 temperature measurements.

Rational & History of requirement: Temperature sensors will be needed to monitor the environment and conditions on the DSTB. Some experiments may require temperature information measured by the FCDS. The temperature of all experiments (average of 10) on the flight will be monitored. At least 10 sensors will be needed to monitor the state of the FCDS and the power system. The remaining 20, and possibly additional sensors, will be used to support the DSTB thermal modeling effort.

D10. The FCDS shall provide a pressure measurement of the ambient environment around the gondola and record the pressure within the FCDS pressure vessel.

Rationale & History of requirement: The characterization of the atmospheric overburden is necessary for proper interpretation of the science data. This pressure parameter is also measured by the SIP and will provide a redundant measurement.

D11. The FCDS shall provide a Global Positioning System and record time and position data.

Rationale & History of requirement: Although the SIP can provide GPS data to the FCDS, there is a possible issue regarding time tag. This can be a critical piece of information for the science activity. The FCDS will need to provide time data to the experiments for them to record and integrate into their data stream.

D12. The FCDS shall provide a minimum of 10 standard communication interfaces to the experiments.

Rationale & History of requirement: During the DSTB workshop, various data interfaces were presented (parallel, serial, digital I/O, and smart port). The RS232 standard interface was requested by a majority of the experimenters. The DSTB will also provide capabilities for RS422, Tbase 10 LAN, and a Smart-port interface as standard options. Communication interfaces other than those listed above will be addressed on a case-by-case basis.

D13. The power system circuit breakers and relays will be commandable by the FCDS.

Rationale & History of requirement: Operationally, the FCDS will be powered on by a discrete command from the SIP. After booting up and assessing the status, commands to the FCDS will turn on one experiment at a time in a preplanned order.

Mechanical Requirements

The following design requirements shall be used in designing gondola structures and suspension. Gondolas must be designed so that all load carrying structural members, joints, connectors, decks, and suspension systems are capable of withstanding the conditions listed below without ultimate structural failure (total failure).

The following assumptions are made by the NSBF certifying engineer in reviewing gondola design analysis:

A. The *suspension point* is defined as the point where the scientist furnished gondola suspension equipment interfaces with the NSBF furnished flight system hardware.
B. The *payload weight* includes the gondola structure, all scientific equipment and components, and all NSBF equipment (including ballast) affixed to the structure below the gondola suspension point.
C. For analysis purposes, the base of the gondola may be assumed to be rigidly fixed (i.e., in a static condition). Other boundary conditions may be used upon prior approval of the NSBF.

Requirements:

M1. Experiments shall be attached to removable mounting plates.

M2. The gondola shall withstand a load 10 times the weight of the payload applied vertically at the suspension point.

M3. For multiple-cable suspension systems, each cable will have an ultimate strength greater than five times the weight of the payload divided by the sine of the angle that the cable makes with the horizontal in a normal flight configuration. Cable terminations, cable attachments, and gondola structural members must be capable of withstanding the load described above. Some exceptions to this criterion may be allowed for gondolas with more than four suspension points at the discretion of the NSBF certifying engineer.

M4. The gondola shall withstand a load five times the weight of the payload applied at the suspension point and 45 degrees to the vertical. This load factor must be accounted for in the direction perpendicular to the gondola's short side, perpendicular to the gondola's long side, and in the direction of the major rigid support members at the top of the gondola structure. If flexible cable suspension systems are used, they must be able to withstand uneven loading caused by cable buckling.

M5. The payload (all components and equipment attached to and/or onboard the gondola structure or any portion of the flight system below the balloon) will withstand a side acceleration of 5 g.

M6. The ductility of all materials used for critical mechanical elements shall be considered in the analysis of the gondola structure. Close examination of all materials that have a percent elongation less than or equal to 10% at an ambient temperature of –60 degrees Celsius shall be made to determine if a material is considered to be brittle. If a material is determined to be brittle, the certification criteria listed in M2-M5 must be multiplied by a factor of 1.5.

M7. The gondola shall meet fastener integrity requirements levied by NSBF per LDB Flight Application Form: GSFC Fastener Integrity Requirements.

M8. The total payload shall not exceed 5500 lbs and the science payload weight shall not exceed 4000 lbs. In selection of the experiments for each flight, the science payload weight shall be consistent with the capability of the balloon to achieve an average float altitude with $<5 gm/cm^2$ of atmospheric overburden.

M9. The payload shall stay within the geometric limitations of the launch vehicle. The payload side facing towards the launch vehicle shall not exceed 20 degrees from the launch vehicle lifting point as shown in Figure 1. The payload shall have a minimum ground clearance of 5 feet between the ground surface and the lowest point of the payload when attached to the launch vehicle payload suspension point. The height of the payload suspension point on the launch vehicle is fixed at 36 feet above the ground surface.

M10. Critical data hardware and experiment samples shall be designed for recovery. The payload shall be modular such that the entire payload can be recovered using the Twin Otter or Helicopter with multiple flights. The largest items shall not exceed 200 lbs. Most components should be designed to be taken apart and handled by one person.

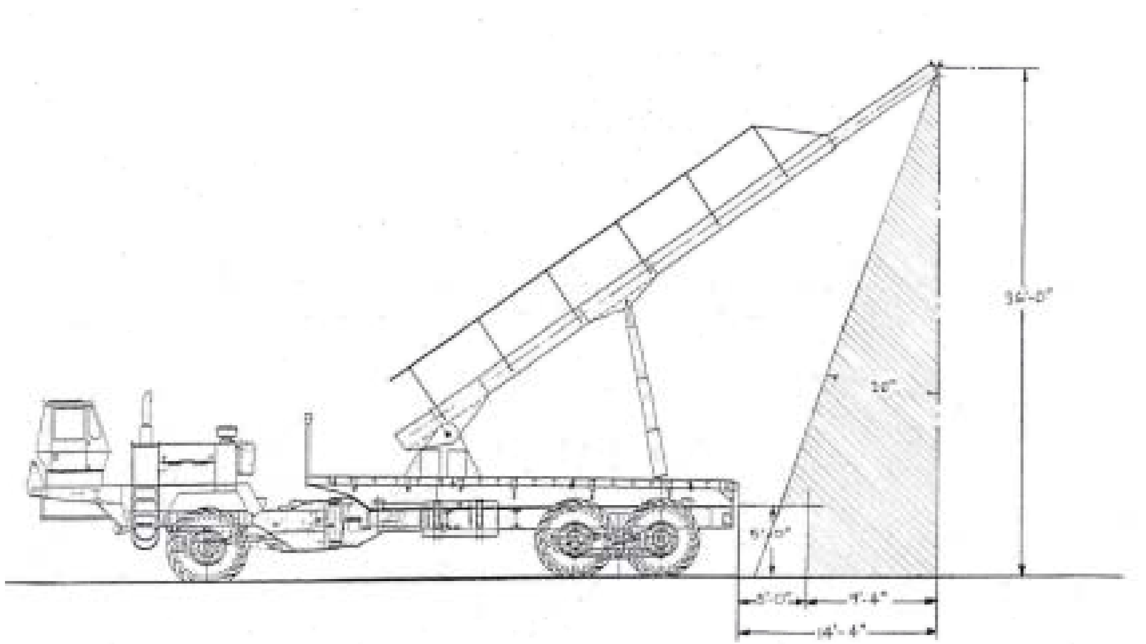

Figure 1: Launch Vehicle Restrictions

Twin Otter limitations:

Door: 56” wide x 50” high

Two hundred pounds per square foot cargo density.

Cargo holding area tapers from fore to aft (final coordination required, diagram of cargo holding area needed for design input)

2200 lbs cargo capability (affected by weather conditions)

Helicopter limitations:

Very limited inside cargo carrying capacity

Can sling loads up to 1800 lbs

Goal:
In most cases the entire payload is recovered eventually. However, critical items will be identified that pertain to science objectives when recovery is limited by time and weather conditions. These items shall be designed to be recovered quickly with minimal manpower and easy access.

4.0 Gondola Mechanical Configuration

The DSTB is a self-contained gondola, which will contain all experiments, electronics and the power system. The payload consists of 5 levels (Figure 2): the exposure deck, the electronics platform, the Balloon Standard Instrument Package (SIP), the SIP solar panels and the DSTB solar panels.

The exposure deck will house the scientific experiments for each mission. The deck can be reconfigured to meet the requirements of a particular mission; however, it will have a basic structure consisting of removable panels. The preliminary design shows eight separate panels each 24″× 24″ on which an experiment will be mounted. The panels can be within the perimeter of the upper deck, or hang over the side so the experiment is more isolated. Crush pads may be added to protect these experiments at ground impact. On some of the flights the exposure deck will also hold a carousel of shielding materials. Detectors will be placed below the materials on the carousel to measure the transmitted radiation. The carousel can rotate during flight to allow different sensors to measure the effective shielding of the material samples. Experiments may

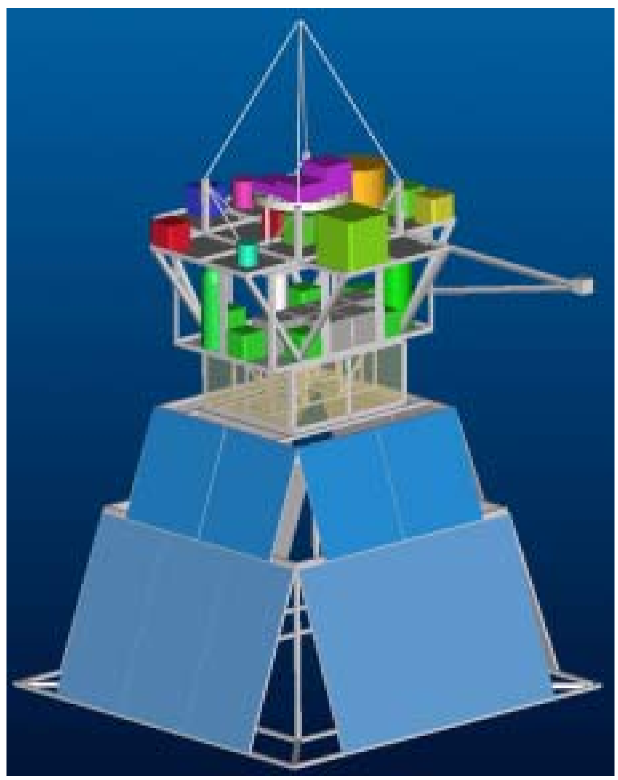

Figure 2. Conceptual drawing of the full DSTB payload. The height is 19.6 ft. and the width is 8 ft. and 11.7 ft. at the exposure deck and solar arrays respectively.

also be placed on booms, allowing the experiments to be placed farther away from the body of the DSTB. Electrical interfaces to each exposure site include a low voltage power connector and two data connectors. The data ports at each site provide an IO port for data transfers, command and control signals as well as digital and analog throughputs to the data acquisition system.

The electronics platform is located directly beneath the exposure deck. This platform houses the electronics required to run the experiments and to interface with the NSBF provided equipment. This will reduce the mass on the exposure deck. An onboard computer controls the operation autonomously during flight and is equipped with data storage. Preprogrammed command sequences are executed by uplink commands. Science data can be returned though the FCDS as well as real-time data on GPS position.

The third and fourth decks contain the NSBF equipment. This includes an independent power system (solar arrays, batteries, DC-DC converters), a data acquisition system for monitoring balloon operations, a bolometer, and a GPS system. In addition to the equipment on these two decks, an NSBF provided receiver-transmitter (RT) for communications will be placed outboard from the exposure deck. The RT provides line of sight telemetry, TDRSS and IMMARSAT links, receives and processes balloon vehicle commands and records the position.

The bottom deck houses the DSTB solar arrays, which provide power to the DSTB electronics and the science experiments on the exposure deck. An NSBF provided remotely controlled ballast hopper will hang down between the DSTB solar panels and will be used to provide altitude control of the balloon.

5.0 User Inputs

Input from members of the scientific community was collected during the DSTB WS. Prior to the meeting, a questionnaire was created and distributed. These questions addressed how each experimenter might utilize the available resources of the DSTB. The responses gave the engineering team an idea of the resources required on the DSTB and how they may be shared by potential users of the DSTB to support their mission. Inputs from this meeting were compiled to cover the areas of mechanical, thermal, power and command and data handling. This section summarizes the information provided by the experiments. The questionnaire is included in the workshop appendix and presentations from the representatives are included in the proceedings for the workshop.

User Presentations

- Eric Benton – Sensor
    - Portable TDL
    - CR-39
    - Dose, dose equivalent, LET Spectra
- Mark Christl – Sensor
    - Charged Particle Spectrometer
    - Measure primary GCR and secondary particles through shielding

- Jerry Fishman – Sensor
    - Low Energy Particle/ Gamma-Ray Detector
    - Neutron spectrometer
- Brad Gersey – Sensor
    - Tissue Equivalent Proportional Counter (TEPC)
    - Dose, Dose Equivalent, LET Spectra
- Raj Kaul –Shielding Materials
- Jim Kinnison/Richard Maurer – Sensor
    - Neutron Spectrometer and Environment Monitor
- Tom Parnell/Rich Miller – Sensor
    - Solar Neutron Tracker (SONTRAC)
    - Directional Neutron Spectrometer
- Robert Richmond – Biology Studies
    - Biodosimeter
    - Cell Exposures
- Dan Saldana – Biology Studies
    - Nemasat : Monitor radiation effects on nematodes (worms)
- Ram Tripathi – Shielding Materials
- Ranji Vaidyanathan – Shielding Materials
    - Light weight radiation shielding material with carbon nanotube reinforcements

5.1 Mechanical Inputs

General

- Expand the exposure deck to provide more separation between experiments.
- Experiments need to be protected to reduce possible damage on landing.
- No experimenters expressed an interest in being on the boom, at this time.
- Gondola mounting plates are to be removable and delivered to the experimenters.
- No experimental requirement for pointed gondola, but pointing knowledge may be useful.

Experiment Specific

- Eric Benton – Sensor
    - Diameter 20 mm x 60 mm
    - 70 grams (with carrying case)
    - Passive
- Mark Christl –Sensor
    - Clear aperture
    - Carousel for multiple material testing
    - 85 lbs
    - 40 x 40 x 40 cm
    - Electronics in a pressure vessel located on electronics deck
- Jerry Fishman – Sensor
    - Satisfied with mounting on the electronics deck
    - Clear view below and to side of gondola
    - Diameter 2” x 2” thick

  - Carousel shielding disks diameter 4”
  - Less than 20” square
- Brad Gersey – Sensor
  - 4 kg
  - Diameter 16 cm x 34 cm high
  - Electronics on electronics deck
- Raj Kaul – Materials
  - Dog house shaped with detector located inside of material
  - 3-5 g/cm^2 most likely
- Jim Kinnison/Richard Maurer – Sensor
  - Satisfied with mounting on the electronics deck
  - 75 lbs
  - 27” x 16” x 13” (can be made smaller)
  - Does not want to be located on a boom
- Tom Parnell/Richard Miller – Sensor
  - Instrument is still in development, will likely fit in 24x24 in^2 footprint.
  - Some electronics can be mounted on electronics deck
- Robert Richmond – Biology
  - Exposure apparatus needs to be developed
- Dan Saldana – Biology
  - No proximity restrictions
  - Recover all of experiment
  - 3 kg
  - 10 x 10 x 30 cm^3
  - Does not want to be located on a boom
  - Sealed experiment in 1 atm
- Ram Tripathi – Materials
  - Details will be provided later
- Ranji Vaidyanathan
  - Possible carousel material

5.2 Power Inputs

General

- 600 watts is sufficient for present gondola subsystems, standard radiation monitors and experiments.
- Experimenters satisfied with DSTB supplying 28 volts DC (±6 VDC)

Experiment Specific

- Eric Benton – Sensor
  - Passive sensors do not require power directly.
  - Portable TLD requires low power and is self contained.
  - Passive thermal control may be sufficient.
  - Temperature monitoring
- Mark Christl – Sensor
  - Estimated 125 watts

- Jerry Fishman – Sensor
    - Power requirements not defined
- Brad Gersey – Sensor
    - Presently runs on 9 VDC but could use 12 VDC or 28 VDC
    - 600 mW
- Raj Kaul – Materials
    - No direct power required
- Jim Kinnison/Richard Maurer – Sensor
    - 10 Watts plus survival heat during ascent
    - Continuous operation throughout the flight
    - 28 VDC
    - Would like ±28VDC
- Tom Parnell/Richard Miller – Sensor
    - Will supply engineering requirements
- Robert Richmond – DNA cell monitoring real time
    - Conceptual, no power requirements at this point in time
- Dan Saldana – Biology
    - 7 VDC
    - Can use 28 VDC
    - Needs battery power to maintain temperature after landing
    - 4 watts steady state, 10 watts active video mode
- Ram Tripathi – Materials
    - No direct power required
- Ranji Vaidyanathan– Materials
    - No direct power required

5.3 Thermal Inputs

General

- Experimenters provide thermal inputs to the DSTB thermal model.
- The DSTB team will develop the thermal model for the entire payload.
- Experimenters will provide their own thermal control.
- The DSTB team will provide NSBF with a thermal model and suppor analysis for the payload.

Experiment Specific

- Eric Benton –Sensor
    - Not particularly temperature dependent
    - Avoid large variations
    - Monitor temperature
- Mark Christl – Sensor
    - Temperature Requirements: 0-25° C
    - Not anticipating active heating or cooling
    - Electronics in a pressurized can

- Jerry Fishman – Sensor
    - Require temperature monitoring
    - Some instrumentation may require temperature variations less than a few degrees.
- Brad Gersey – Sensor
    - Temperature Requirements: 0-50° C
- Raj Kaul – Materials
    - Ambient temperature is suitable.
- Jim Kinnison/Richard Maurer – Sensor
    - Temperature Requirements: 5-20° C
    - Active heating
    - Sealed canister at 1 atmosphere
- Richard Miller – Sensor
    - Thermal requirements yet to be defined
- Robert Richmond – Biology Exposures
    - Thermal requirements vary
- Dan Saldana – Nemasat (Monitor radiation effects on worms)
    - Temperature Requirements: Operating: 5-15° C; Non-operating: 5-30° C
    - Active heating needed especially after landing
    - Sealed canister at 1 atmosphere
- Ram Tripathi – Materials
    - No specific requirements given
- Ranji Vaidyanathan – Materials
    - Ambient temperature suitable

5.4 Flight Data & Control System Inputs

General

- DSTB will provide the interface between the experiments and NSBF's SIP.
- Data storage will be available on the DSTB.
- Standard communication interfaces will be available.
- Custom communication interfaces will be addressed individually.

Experiment Specific

- Eric Benton – Sensor
    - Communication interface to Portable TLD
    - Passive detectors require no interface.
- Mark Christl– Sensor
    - 100 Mb/day compressed
    - Data recorded on DSTB storage device
    - Requires telemetry to the ground station
    - High rate LOS telemetry at start of mission
    - Daily communication to upload commands
- Jerry Fishman – Sensor
    - Data storage on flight data system
    - Communication interface for telemetry and commanding

- Brad Gersey – Sensor
    - 1.2 Mb/day on an RS232 line; continuous or once a day
- Raj Kaul – Materials
    - No data system interface requirements supplied
- Jim Kinnison/Richard Maurer – Sensor
    - Data collection internal to experiment
    - Data recorded on DSTB storage device
    - Requires telemetry to the ground
    - 256 Mb
    - 64 k/hour
    - Data recorded by ground station
    - Experiment commanded from the ground
    - Experiment needs to communicate to the ground during flight.
    - Polling by DSTB not required but might be desirable.
- Tom Parnell/Richard Miller – Sensor
    - Data storage on flight data system
    - Communication interface for telemetry and commanding
    - Interface type to be determined
- Robert Richmond – Biology
    - Exposure apparatus is conceptual.
- Dan Saldana – Biology
    - Data collection internal to experiment
    - Data recorded on DSTB storage device
    - Requires telemetry to the ground
    - 60 Mb/day
    - Data recorded by ground station
    - Experiment commanded from the ground once a day
- Ram Tripathi – Materials
    - No data system interface requirements supplied.
- Ranji Vaidyanathan – Materials
    - No data system interface requirements supplied.

6.0 DSTB Thermal Environment

The major sources contributing to the thermal environment of the balloon flight missions are (1)-direct sun light, (2)-reflected sun light from the Earth, and (3)-IR emission from the Earth. The nominal solar flux experienced during the Austral summer season is 1348 watts/m^2 with the Earth's albedo being as high as 95% when the balloon trajectory encounters a fresh blanket of snow. During ascent in the southern polar region, temperatures as low as -45ºC to -50ºC will occur while traversing the Tropopause. When the float or ceiling altitude is reached, convection becomes negligible due to a low ambient pressure of 4 to 5 millibars.

In order to model the radiation exchange between the gondola surfaces and the external thermal environment, the Thermal Radiation Analyzer System (TRASYS) analysis software is used. The accuracy of this computer code partly depends on the number of surfaces modeled. The available optical surface materials can range from silverized Teflon® ($\alpha/\varepsilon = 0.125$) to Tedlar white paint ($\alpha/\varepsilon = 0.45$) to stainless steel ($\alpha/\varepsilon = 1.41$) and bare aluminum ($\alpha/\varepsilon = 3.5$). The parameter α is the absorptivity and ε is the emissivity of the surface material. Noting the high values of α/ε, any exposed metal surfaces should be avoided. The results of the TRASYS program serves as input for the Systems Improved Numerical Differencing Analyzer (SINDA) computer program or similar program. The SINDA analysis tool is used to construct a resistor/conductor network for the gondola and every experiment attached to the DSTB platform. The accuracy of SINDA depends on the number of network nodes included in the thermal model of the entire DSTB and the accuracy of the thermal model parameters.

Initially, passive methods should be employed to control the experiment temperature within predefined limits and, if necessary, reduce the temperature gradient in critical areas of the payload. This means specifying insulation materials, optical surface coatings, and heat pipes to establish a temperature profile for each experiment over the course of a DSTB balloon flight. Some of the principal investigators may want to thermally isolate their experiments from the DSTB gondola. Power may be used for heating and cooling to further control the temperature of an experiment during the prelaunch preparation, ascent, and flight phases of the DSTB high-altitude balloon mission.

The NSSTC/MSFC organization will be responsible for the thermal modeling of the integrated DSTB gondola while each principal investigator will provide a thermal model of his individual experiments.

7.0 DSTB Radiation Environment

An excellent starting point in the description of the space radiation environment for the DSTB balloon missions is the examination of the free space galactic cosmic ray spectra derived from the Cosmic Ray Effects on Micro-Electronics (1996 revision) suite of programs better known as CREME96. The free space galactic cosmic ray flux near the Earth is bounded by the solar wind intensity evaluated as solar activity cycles between a minimum and maximum as measured by the sunspot number. The Excel presentation included in the DSTB proceedings (J.Watts) includes a representative sample of the cosmic ray energy spectra, namely, the elements hydrogen, helium, nitrogen, and iron. This free space cosmic ray flux will be transformed in two ways before it reaches balloon altitudes (≈ 38 km). Depending on their rigidity (pc/Ze in GV), the cosmic rays can be rejected by the Earth's magnetic field and can be further blocked by the Earth's shadow. At balloon altitudes, the cosmic rays are transported through an overburden of the atmosphere equaling 4 to 5 g/cm^2 which is equivalent to 1.7 cm of Aluminum. This results in the nuclear fragmentation of some of the cosmic rays that depends on their atomic mass and, to a lesser extent, on their energy.

A selected subset of the subroutines in the CREME96 computer program was modified so that a suborbital balloon flight can now be modeled. Specifically, a suborbital balloon flight with fixed latitude and a typical altitude of 40 km can be treated. The primary case of interest is a balloon flight in the Antarctic region launched from McMurdo (77º 50' S, 166º 36' E). For this balloon flight trajectory, there is a zero vertical cutoff rigidity between 10º and 230º E

Longitude. If Fairbanks, Alaska (64º 49’ N, 212º 15’ E), were to be chosen as the launch site, the vertical cutoff rigidities are not as low (i.e., the vertical cutoff rigidity, ≤ 0.1 GV, is only between 230º and 340º E Longitude). In the Excel presentation, both the proton and iron energy spectra for the solar minimum period (the maximum flux) are plotted for the following cases; (1)-free space flux, (2)-120 kft at McMurdo and Fairbanks correcting only for the vertical geomagnetic cutoff , and (3)-120 kft at McMurdo and Fairbanks with the transport through 5 g/cm^2 of atmosphere included. As a complete contrast to the Polar Regions, a low latitude launch site, Alice Springs, Northern Territory, Australia (23º 42’ S, 133º 52’ E), is also presented. For reference, the geomagnetic North Pole as of 1996 is located at 79.3º N, 288.5º E and the geomagnetic South Pole is located at 79.3º S, 108.5º E.

The albedo neutron flux from the atmosphere can be estimated by the use of the Wilson-Nealy model which compares very well with existing measurements (see DSTB Proceedings, J. Watts). The Wilson-Nealy predictions of the albedo neutron flux in the energy interval, 1-10 MeV, for both solar minimum and solar maximum is plotted against the atmospheric depth for a rigidity of 0.5 GV. A similar plot is made as a function of rigidity for an atmospheric depth of 5 g/cm^2 applicable during solar minimum.

In conclusion, there are several remaining issues that need to be addressed. The incident cosmic ray angular distribution at balloon altitudes along with the corresponding angular distribution of the produced secondary particles has yet to be estimated. In addition, the precipitating electrons and bremsstrahlung and the solar particle events are still to be added to the radiation environment. These features will continue to be studied for the DSTB project.